

Date of publication xxxx 00, 0000, date of current version xxxx 00, 0000.

Digital Object Identifier 10.1109/ACCESS.2017.Doi Number

Mobility Management in 5G Networks and Beyond: A Survey

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This work supported by TÜBİTAK Project No. 118C276, and it was supported in part by the Department of Commerce under Grant BS123456.”

ABSTRACT In the near future of mobile networks, the massive deployment of Base Stations (BSs) will be for Fifth Generation (5G) and Sixth Generation (6G) systems. This is because 5G and 6G networks will use millimeter waves (mm-waves) that provide very small coverage in Line-Of-Sight (LOS). The case becomes more critical if higher mm-waves are used in 5G or 6G networks. This will certainly create significant connection problems, particularly during the users’ mobility over these various networks. Specifically, it will lead to a massive increase in Handover Probability (HOP), Handover Failure Probability (HFP), Handover Ping-Pong Probability (HPPP) effect, Radio Link Failure (RLF), interruption time, and throughput degradation. Support for high mobility speed is one of the essential requirements needed in wireless networks, especially in 4G, 5G, and 6G systems. The new mobile systems (IMT-Advanced and IMT-2020 and beyond) can support high mobility speeds of up to 500 km/h. Such systems will also dramatically increase mobility issues. Therefore, ensuring a seamless connection during users’ mobility will be one of the major challenges facing the implementation of future heterogeneous networks. Mobility issues in future 5G and 6G networks must be efficiently addressed in order to provide seamless communication during users’ mobility. Therefore, the aim of this paper is to provide an overview of mobility management in 5G and 6G networks. This work examines mobility management in future heterogeneous networks that consist of 4G, 5G, and 6G networks with IoT Technology. The study further highlights the main challenges facing users’ mobility in mm-wave systems. Subsequently, the innovated, advanced, efficient, and smart handover techniques that have been introduced in 5G and 6G systems are discussed.

INDEX TERMS Mobility Management, Mobility Robustness Optimization, Self-Optimization, 5G Systems, Future Ultra Dense Networks, Handover

I. INTRODUCTION

The 5G and soon-to-be 6G wireless systems are the next proposed telecommunication standards beyond the current 4G/International Mobile Telecommunications Advanced (IMT-Advanced) standard. The plans for 5G and 6G wireless systems are currently in progress and will potentially affect mobile phones and wireless connections confined under the Internet of Things (IoT), Machine To Machine (M2M), Device To Device (D2D), Vehicle To Everything (V2X), and Bluetooth connections. Collectively, they will impact businesses, governments, and customer interactions in the physical world [1-9]. They are starting to significantly grow since customers, businesses, and governments now recognize the benefits of connecting inert devices to the internet. In the next ten years, IoT, D2D, M2M, V2X, and Bluetooth will be the largest device markets in the world [10-12]. It is expected that there will be hundreds of thousands of simultaneous connections

deemed essential for the massive deployment of IoT, D2D, M2M, V2X, and Bluetooth services in 5G and 6G systems [13-15]. This will require more system capacity, lower latency, and greater data rates. All these necessary requirements have led to the development of 5G, followed by 6G, systems which mainly aim to provide massive capacity, high data rates, lower latency, lower battery consumption, and reduced cost versus 4G systems [13, 14, 16, 17]. However, high data rate demands require a very wide bandwidth to meet and fulfill user satisfaction. The required bandwidths for 5G and 6G systems are more than ten and fifty times than what is required for 4G system [13, 14, 16-18], respectively. This high demand is the key factor for proposing mm-waves to be used in 5G and 6G systems due to the availability of wider bandwidth in these bands [19, 20]. These bands are located between 10 GHz and 300 GHz [19], while the bands of 10 GHz to 86 GHz spectrum have been recommended as the best candidate bands for 5G

systems [20-22] by the International Telecommunication Union (ITU) [21], numerous industries [22], and many research centers [20]. These candidate bands have also been explained in several researches [23, 24]. From these bands, the 28 GHz is currently the most recommended band for the 5G system [25-28]. Regarding the 6G system, the mm-wave bands up to 120 GHz are recommended [13-15].

The small coverage provided by mm-wave bands is one of the main issues that will face the implementation of 5G and 6G systems in future heterogeneous networks. These bands located above 10 GHz means that the operating frequency will be very high, which will cause greater path loss. That will shorten the provided coverage in 5G and 6G systems operating on mm-wave bands. For example, 28 GHz is one of the best candidate frequency band that can be implemented in 5G mobile broadband systems, but this frequency band can support only up to 200 meters in LOS [29, 30]. So, in order to cover an area of a few kilometers by the 5G system, a massive number of 5G base stations/access points will be deployed. Compared to the 4G system with 2.1 GHz, one 4G cell can cover up to 1.5 km [31-36]. On the other hand, replacing one 4G cell with 2.1 GHz by a 5G cell with 28 GHz will require more than fourteen 5G cells in order to provide similar coverage provided by one 4G cell ($r = 1.5$ km). This is because the 5G cell can provide only around 200 meters of coverage in LOS. These massive numbers of small 5G cells will lead to a high number of handover probability during the users' mobility which, in turn, will lead to a high increase in the probability of HFP, HPPP effect, RLF, interruption time, and throughput degradation. In addition, the handover failure will further increase due to the small cell size, especially with higher mobility speeds. This is because mobile users with high mobile speed may cross the cell within a few seconds, and this will reduce the completion probability of the handover procedure.

Overlapping deployment in future heterogeneous networks is another concern that may arise as a mobility issue. This is because 5G and 6G systems will be deployed overlapping the current heterogeneous networks (Second Generation (2G), Third Generation (3G), and Fourth Generation (4G) networks) and even future IoT networks. That will make future heterogeneous networks more overlapping, which will consequently increase the types of handover scenarios. This will also significantly contribute to rising handover rates during the users' mobility which will increase the handover probability, leading to a significant escalation in HFP, HPPP effect, RLF, interruption time, throughput degradation, and the overhead and overall communication performance quality [37-51]. The drawbacks become more critical through high mobility speeds; particularly when there is no mobility robustness optimization technique or efficient handover decision algorithms used. Thus, these issues must be considered and addressed as well.

The number of mobile connection growths is also another significant problem facing the implementation of future cellular networks. This is because the increase in mobile connections will lead to a radical increase in the demand for mobile data traffic. Since the system bandwidth provided by 4G and 3G base stations is insufficient, 4G or 3G base stations will be unable to serve a high number of users within the cell. The 5G will be deployed while overlapping 3G and 4G networks, therefore, part of the 3G's and 4G's mobile connections will be switched to 5G cells in order to balance the load and reduce the traffic congestion of 3G and 4G networks. This will lead to a tremendous increase in the handover probability from 3G and 4G to 5G BSs. As a result, a significant rise in HFP, HPPP effect, RLF, interruption time, throughput degradation, and overhead and overall communication performance quality will occur.

All these issues will degrade mobile connectivity, connection reliability, and stability during the user's mobility. In order to solve these issues, advanced mobility management and handover self-optimization techniques are required to efficiently address these problems. Implementing efficient dual connectivity mechanisms will enable users to have reliable and stable connection with serving networks during their mobility. In other words, addressing mobility issues in 5G and future systems can be performed by implementing more advanced, robust, and efficient handover techniques. One significant and required handover technique is by efficiently managing the Handover Control Parameter (HCP) settings. Several solutions were proposed for 4G systems to address mobility issues, and a few solutions were also proposed for 5G networks. Therefore, controlling the mobility management requires efficient mobility techniques to effectively provide continuous service to users.

Consequently, this paper presents a comprehensive overview on mobility management for 5G networks and beyond. In this study, we take a closer look at the trends that will direct mobility issues over the next future networks (5G and 6G networks). They include the opportunities, challenges, practical issues, and performance evaluation which will contribute to the development of 5G and 6G networks. The aim is to provide a general idea of mobility issues that will be faced during the implementation of 5G and 6G systems, which will probably be launched in the near future. This study will discuss the essential issues that will lead researchers to innovate, design, and formulate advanced, efficient, and smart handover techniques that can manage handover optimization, handover decisions, dual handover, and seamless handover procedures for 5G networks and beyond. Additionally, the study will lead 5G and 6G systems and future heterogeneous network developments and exciting wireless technology expansion.

The rest of this paper presents the following: Section II provides an overview on mobility; Section III presents and discusses mobility challenges in 5G networks; Section IV

provides a brief description of advanced mobility solutions; and Section V discusses the conclusion of this paper.

II. MOBILITY OVERVIEW

Mobility in wireless networks is basically known as the continuous support of communication to the user during movement. In other words, mobility is fundamentally identified as the ability to maintain a user's connection with the serving wireless network during movement within cells without any disruption in the ideal case. Therefore, it is considered as one of the essential and significant features provided by wireless communication networks as compared to wired networks. This feature enables the mobile user to switch connection from one cell to another during their movement. The movement of users means the periodical changes in mobile locations, which leads to a change in the received cellular signal strength level. Once the received signal strength falls below an acceptable level (RSSI: Received Signal Strength Indicator, also known as the RSS threshold level) at any specific location, the user requests switching the connection to another neighboring cell that provides good signal strength. Therefore, connection will be maintained with the serving networks for the user during mobility without any disruption in the ideal case. Although mobility is one of the significant features provided by wireless systems, not all wireless systems support mobility. This is because some users and wireless communication systems have been designed to support fixed wireless stations without mobility. In some cases, these wireless systems can support mobile users but with very limited mobility, which can be introduced as partial mobility (such as a cordless wireless system). Therefore, not all wireless communication systems and even users can support mobility. Mobility can be supported by wireless systems and even users, but only those who have and support **mobility functions**.

Mobility functions are essential roles for mobility support in wireless communication networks. They enable the mobile user to switch connection from one cell to another during movement without any disruption. There are several mobility functions that can support mobility such as mobile Internet Protocol (IP), handover decision, handover optimization functions, and rerouting mobile protocols. Some wireless networks support mobility functions, while others do not. For example, cellular systems, wide-area mobile data systems (i.e., Mobile WiMAX), Wireless Local Area Networks (WLAN), and several satellite systems support mobility functions. On the other hand, cordless networks, fixed wireless networks (i.e., fixed WiMAX), some satellite systems (satellite TV services), radio, and Bluetooth systems do not support mobility functions. With the support of mobility functions, the users can have

flexibility during their mobility. They can switch the connection from one cell to another as long as coverage is available. The support of mobility functions increase user satisfaction and enable wireless services to be available at anytime and anywhere. This means that the mobility functions enable users to have easy access to wireless networks from a wider geographical area and for many purposes. Mobility functions support different mobility speeds depending on the wireless system. They enable users to maintain their connection during their movement in cars, buses, and trains with various mobility speeds.

Mobility speed is one of the significant criteria considered in mobility research. This is because different users can have various speeds which have diverse impacts on the received signal strength during user mobility; the varied speeds will influence communication stability. Since mobility is one of the critical features in wireless systems, supporting a specific mobility speed becomes an essential requirement that must be fulfilled for each wireless system, specifically mobile cellular systems. Therefore, different wireless communication systems can support various mobility speeds. For instance, the 4G cellular system can support up to 350 km/hr [52], while the 5G cellular system can support up to 500 km/hr [53]. The reason behind that is due to several key factors in the system architecture, protocols, and functionalities used such as round communication latency, network architecture, the employed frequency, and node processing time. Although the new wireless systems support higher mobile speeds, the increase in mobile speed leads to critical issues during mobility. Therefore, several mobility techniques have been proposed to address the various issues that arise during different mobile speeds.

Efficient mobility techniques mean the mobility procedures, methods, mechanisms, and protocols that work efficiently to support reliable and stable connection during users' mobility. There are various mobility techniques and functions that can be applied to support mobility. One example would be the techniques used for regulating mobility control parameters, known as Handover Self-Optimization functions. Another example is the mechanisms used for making handover decisions, known as handover decision algorithms. There are also the protocols applied for rerouting data or voice calls to the new routing path, known as mobile routing protocols. The techniques utilized for reducing handover delay, or improving handover procedure, can also support mobility. Implementing efficient mobility techniques will lead to seamless connections throughout user mobility within cells. This will guarantee a reliable connection and provide good service quality. There are several techniques that have been proposed in the literature for addressing mobility issues. Nonetheless, there is no optimal mobility technique that can

fully address the current mobility issues. Therefore, these issues are still an open area for research in the new mobile communication systems, such as 5G and 6G systems.

In 5G and 6G Mobile Broadband (MBB) systems, mobility management becomes more significant and critical. This is due to several reasons such as the use of mm-waves, the massive growth of mobile users, various types of connections, the need for very fast round connections, the demand for high mobility speeds, and the need for ultra-reliable communication applications. The use of mm-waves [19, 20] is the main factor that makes mobility issues more complicated in 5G and 6G systems. This is because these bands can provide very small coverage which leads to increased mobility problems. New types of mobile connection systems will emerge and rise in future networks. They will consist of IoT, M2M, D2D, V2X, Bluetooth,

mesh Wi-Fi, 3G, 4G, 5G, and soon 6G connections, as illustrated in Figure 1. Implementing these systems will significantly contribute to the increase of mobility issues as well. The massive growth of mobile users leads to congestion in the serving network. Implementing a massive number of small base stations that overlap with current networks will be required, as illustrated in Figure 2. This will raise the demand for handover. Collectively, these issues will lead to an increase in mobile data traffic in future. This rapid growth will also contribute to the high probability of handover rate. Handover interruption time is another critical issue that will occur in 5G and 6G networks. This is because the 5G cell size is very small and the handover probability will be very high, leading to a significant increase in the interruption time. Thus, handover processing time must be very short.

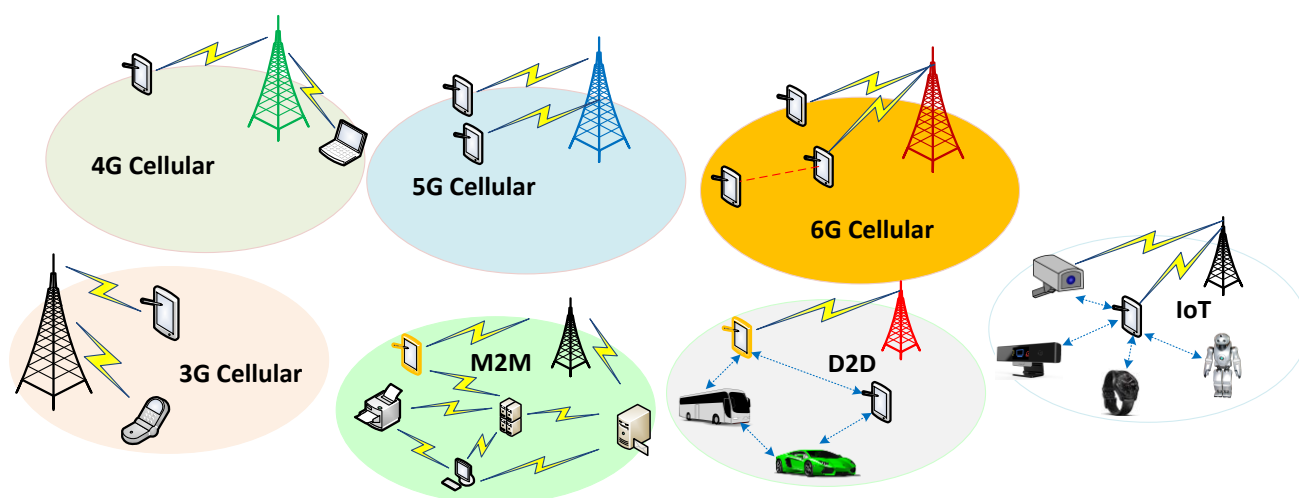


FIGURE.1. Types of mobile connections deployment in future wireless networks

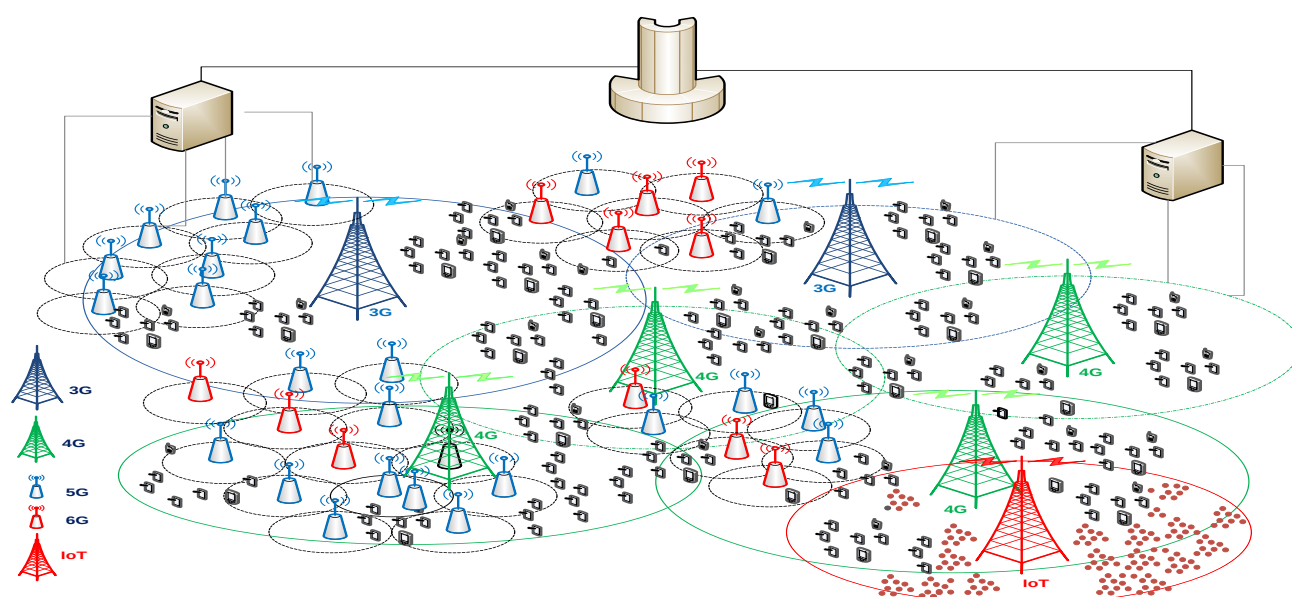


FIGURE.2. Ultra-dense heterogeneous networks

III. MOBILITY CHALLENGES in 5G NETWORKS

The communication performance in 5G and 6G systems in future heterogeneous networks will be dramatically affected by the introduction of mm-wave bands since they provide very small coverage. The effect will be more critical with the massive IoT, D2D, M2M, V2X, and Bluetooth connections that will be implemented in 5G and 6G systems. As compared to Long-Term Evolution (LTE) of 4G, Long-Term Evolution-Advanced (LTE-A), and 3G systems, new mobility scenarios will be added as a result of implementing mm-waves in 5G and 6G systems. The massive IoT, D2D, M2M, V2X, and Bluetooth connections will add more new mobility scenarios as well. These will increase the HOP, HFP, HPPP, and RLF effects. This new handover scenario occurs according to the signal quality and channel conditions related to the User Equipment (UEs) behavior and the HCP settings. Thus, investigating the communication performance during users' mobility in heterogeneous networks which includes 5G and 6G systems with massive IoT, D2D, M2M, V2X, and Bluetooth connections would be crucial for improving users' experiences. Proposing methods to optimize HCP settings is also necessary for improving the overall system performance. Typically, the UE performs handover based on a set of HCPs estimated in the system and assigned to all UEs. The optimal handover decision algorithm triggers the handover request when the HCP criteria are met. Thus, optimizing the HCP settings and handover decision algorithms are key approaches for enhancing mobility performance in 5G and 6G systems with future heterogeneous networks.

If HCP settings are adjusted to fixed settings, this will negatively affect ongoing calls, especially when the UE speed is substantially high. Thus, HCP settings should be suitably adjusted to address this shortcoming. However, doing this manually will increase the management and maintenance complexity. Thus, the Handover Parameter Optimization (HPO) algorithm has been introduced by 3GPP as a fundamental feature to deploy 4G and 5G systems and automatically estimate the appropriate HCP settings. Although the HPO (the conventional HPO) has contributed in reducing handover problems, this algorithm is not the most ideal solution for optimizing HCP settings. Therefore, several studies have been conducted to address this shortcoming.

According to existing studies in the literature [42, 54-58], there are available algorithms that provide efficient optimization for HCP settings, but no optimal solution exists. Most proposed algorithms only adjust HCP settings according to a single parameter, such as distance or velocity. Since there are several influencing factors that should be considered for estimating appropriate HCP settings (such as distance, channel condition, noise, interference, resource availability, and UE's velocity), simply approximating these configurations in the perspective of a single factor will only lead to inadequate HCP settings. Some of these algorithms, such as Adaptive Handover Algorithm, are based on distance

(AHOA-D) [59], velocity [60], and a Fuzzy Control (FLC) algorithm [61]. The FLC algorithm only adjusts the Handover Margin (HOM) level, while the Time-to-Trigger (TTT) is set to a fixed value. This malfunction reduces the main purpose of the HPO task. All highlighted algorithms perform optimization for each cell except AHOA-D. This may allow some UEs to perform handover to other cells while not needing the handover procedure at that time. Therefore, unnecessary handover probability will increase as a result of suboptimal HCP settings. There is a lack of research that focus on optimizing HCP settings based on multiple influencing factors. It can be stated that only non-robust and suboptimal algorithms are present for selecting appropriate HCP settings in future heterogeneous networks with the existence of 5G and 6G systems. Research on handover parameter optimization in heterogeneous networks with existing 5G and 6G systems is one of the most significant issue that should be highlighted and validated in current research. Advanced, dynamic, and robust HPO algorithms that estimate appropriate HCP settings based on multiple influencing parameters are urgently needed.

In addition to the handover parameter optimization problem, the HPO and Load Balancing Optimization (LBO) are two algorithms that aim to optimize system performance by automatically adjusting HCP settings. Since these two algorithms adjust the same HCP settings for the same cell, they may be dependent on each other, where the action of one algorithm may have an influence on the other algorithm. This situation is defined by 3GPP as "Self-Optimization Network (SON) functions in conflict". This conflict can occur when HPO and LBO functions adjust the same HCP settings in the same direction with different scales or in two opposite directions, as illustrated in Figure 3. That can occur simultaneously or in two different periods. Thus, a conflict can be detected because of this complex relation between HPO and LBO algorithms. This detected conflict can be classified into two different types: (i) a simultaneous conflict, and (ii) a non-simultaneous conflict. The simultaneous conflict occurs when HPO and LBO algorithms perform optimization at the same time. The non-simultaneous conflict occurs when HPO and LBO algorithms perform optimization at a different time.

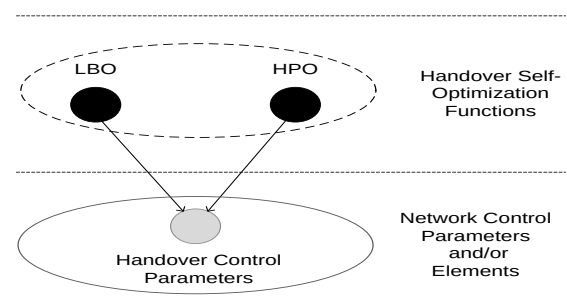


FIGURE 3. The mesh relationships between LBO and HPO algorithms and HCPs

Consequently, the HCP settings can be simultaneously modified twice. This parallel optimization process produces conflicts and the network behavior becomes unstable. Thus, one of these two algorithms will be unable to achieve the specified SON objectives since they may have conflicting interests on network resources. Avoiding this conflict is hardly possible unless one of these two algorithms is disabled. However, disabling LBO or HPO algorithms will not satisfy the prerequisite that both load performance and handover performance must be enhanced simultaneously. Therefore, several coordinated algorithms have been proposed to mitigate, prevent, or resolve this problem. Although several proposed solutions described in the literature are aimed at solving the problem, it has not been fully solved. One of the major reasons for the resulting problem is the central optimization. In addition, existing solutions perform coordination using a single factor while neglecting other influencing factors. That usually enhances system performance in one side while degrading it on the other side. According to these solutions, no optimal coordinated solution exists in the literature. Thus, the study of handover coordination is still an open area for research. This type of research is one of the most significant issues that should be developed in current studies of future heterogeneous networks with the deployment of 5G and 6G systems.

The improvement achieved by optimizing HCP settings in heterogeneous networks may be hindered without an efficient Handover Decision (HOD) algorithm. Thus, the importance of implementing an efficient HOD is equivalent to the optimum estimation of the HCP settings since it is the first line of the handover process. Most of the work in HOD algorithms are proposed for 3G and 4G networks, which have a wider base station coverage compared to that of 5G and 6G systems. Since the mm-waves are adopted in 5G and 6G systems, their impact on the performance of HOD is not thoroughly covered in the literature.

In conclusion, although future heterogeneous networks will have benefitted from the implementation of 5G and 6G systems, issues related to mobility management will further increase. The advent of IoT technology will add additional handover scenarios, more than those found in previous heterogeneous networks. This will lead to an increase in handover probability, unnecessary handover, failure of handover, and RLF probabilities. Those, in turn, will lead to a high reduction in users' spectral efficiency and throughput. In consequence, high interruption time will result, which may lead to increased service disruptions. These phenomena can be frequent if suboptimal HCP settings are assigned. As previously illustrated, the HCP settings can be automatically optimized by the HPO and LBO functions in order to assign

the appropriate HCP settings. The HPO algorithm adjusts HCP settings for the purpose of enhancing the system performance in terms of HOP, HPPP, and RLF. On the other hand, the LBO algorithm adjusts HCP settings in order to balance the loads between cells. Although HPO and LBO algorithms contribute to the enhancement of network quality and load balance, respectively, issues related to high HOP, HPPP, HFP, and RLF have not been thoroughly addressed yet. This indicates the need for more optimal estimation of HCP settings with the use of robust HPO and efficient LBO algorithms. Since HPO and LBO algorithms adjust the same HCP settings, a conflict can result due to the complex relationship between the two algorithms' estimation. This conflict leads to degraded network quality. Thus, a coordinated solution is necessary for solving this problem. Although robust HPO and efficient LBO algorithms will lead to enhanced system performance, more efficient handover decisions are also required [62-64]. Therefore, estimating the optimal HCP settings by HPO and LBO while enabling coordination between them and designing an efficient handover decision algorithm are the most significant factors that can effectively solve mobility problems in future heterogeneous networks.

The main problems related to the area of mobility management research which must be addressed in heterogeneous networks with the deployment of 5G and 6G systems and the massive implementation of IoT, D2D, M2M, V2X, and Bluetooth connections can be summarized as follows:

- (i) High handover probability, unnecessary handover, radio link failure, and outage probability through users' mobility in 5G and 6G systems and in future heterogeneous networks, especially with high mobility speeds, are mainly due to the use of mm-wave bands which provide very small cell coverage.
- (ii) Self-optimization algorithms are non-robust and suboptimal for selecting appropriate HCPs in future heterogeneous networks with the deployment of 5G and 6G systems and the massive implementation of IoT, D2D, V2X, and M2M connections.
- (iii) The optimal solution for LBO and HPO functions consist of complex relation and their conflict problem. In future ultra-dense systems, the issues become more critical. This is because the massive number of mobile connections and ultra-overlapping dense networks in future networks will increase the operation of HPO and LBO functions. This will lead to an increase in conflicting operations of these two functions, defiantly raising the overall handover issue.

- (iv) Handover decision algorithms are inefficient in heterogeneous networks with the deployment of 5G and 6G systems, particularly with the massive implementation of IoT, D2D, V2X, and M2M connections. Thus, current handover decision algorithms will be insufficient in 5G and 6G systems.

IV. ADVANCED MOBILITY SOLUTIONS

One of the significant features that have been introduced to solve mobility problems in 4G and 5G systems is the Self-Optimization Network (SON) [65-76], which will be one of the main component in the 6G system. This feature is one of three main sub-networks that has been introduced under the Self-Organization Network in 4G and 5G systems, as illustrated in Figure 4. The main aim of the self-optimization network is to automate the management process by dynamically adapting system parameters. Automatic adaptation of system parameters is accomplished by integrating a variety of self-optimizing functions to improve system quality and reduce network complexity. HPO and LBO are among the significant functions (algorithms) introduced in the self-optimization network, as illustrated in Figure 5 [65-72, 77, 78]. Both functions aim to dynamically optimize HCP settings to handle different handover problems. For example, the HPO function adaptively adjusts HCP settings to maintain system quality and perform automatic optimizations for HCPs with minimal human intervention; on the other hand, the LBO function can adaptively adjust HCP settings to balance the load over adjacent cells.

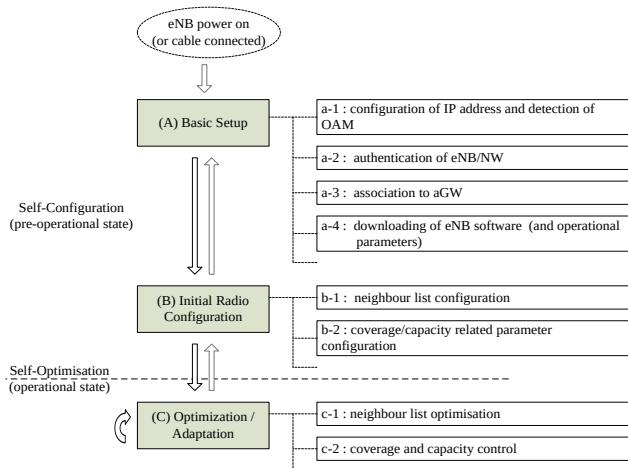


FIGURE 4. The functionality of Self-Configuration and Self-Optimization

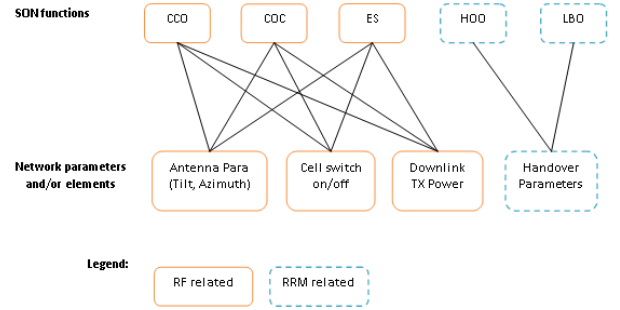


FIGURE 5. Self-Optimization functions and their mesh relationship with parameters [79]

HPO Function has been introduced as a fundamental feature in the deployment of 4G and 5G system. This function adaptively adjusts HCP settings to maintain system quality with minimal human intervention from the operator. Specifically, HPO's target function is to detect and perform corrections of both the RLF and the ping-pong effect due to mobility. In other words, the HPO algorithm adaptively adjusts the HCP settings when RLF or ping-pong is detected as a result of one or more of the following causes:

- "Too Early Handover", as described in Figure 6 (a),
- "Too Late Handover", as described in Figure 6 (b),
- "Handover to Wrong Cell", or
- Inefficient use of system resources caused by unnecessary handover.

Thus, if RLF or HPPP is detected as a result of suboptimal HCP settings, the HPO algorithm is enabled to adjust HCP settings for the related cell to solve the handover problem.

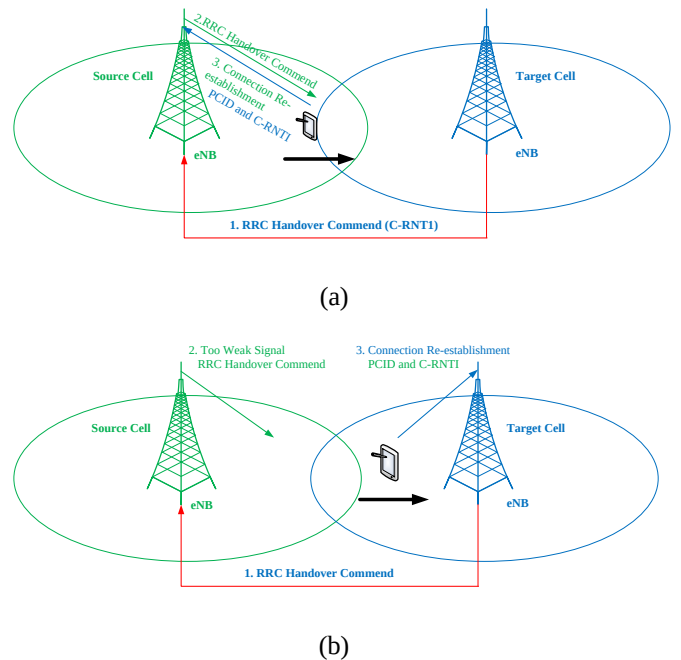


FIGURE 6. Handover problems due to suboptimal HCPs settings, (a) 'Too early handover', and (b) 'Too late handover' [80]

LBO Function adaptively adjusts HCP settings to balance the unequal load between cells. Cell load balance is required when two cells' coverage overlap, two cells' hierarchical coverage overlap, or neighboring cells' coverage overlap, as described in Figure 6. Thus, when the loads between these two cells are unbalanced, the LBO algorithm is enabled to adjust HCP settings of the corresponding cell. This is accomplished to handover the UEs located at the cell edge to the cell that provides more resources and has fewer loads. The operation of the LBO algorithm initially begins by monitoring the cells' load and then exchanging the related information within the neighboring eNBs over X2 or S1 interfaces. Based on this information, the load of each cell is indicated to be either low, mid, high, or overloaded. The serving eNB selects the suitable target cell based on the load's indication. Consequently, the LBO algorithm is enabled when the serving cell becomes overloaded and the load of the selected target cell is less or equal to the average load. On the other hand, if the serving cell load does not reach the overloaded level, the LBO algorithm will not be enabled.

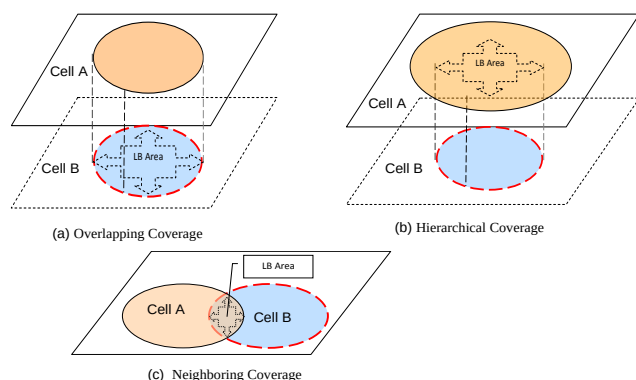


FIGURE 7. Coverage scenarios for balancing load between cells

In addition to these two self-optimization functions as solutions for mobility management issues, designing an **efficient handover decision algorithm** is the other key factor that can contribute in solving mobility problems. An efficient handover decision algorithm is a significant functionality that can control the handover rate; it is the essential step of the handover procedure between serving and target cells. Since an efficient handover decision algorithm contributes in providing a seamless connection between the UE and serving network, it should be efficiently designed in order to perform and make a proper handover decision for the suitable target cell. In the literature, there are several handover decision algorithms that have been introduced to further enhance handover performance [42, 62, 81, 82]. These algorithms were designed based on various parameters and were mostly investigated in different wireless systems.

Dual Connectivity (DC) is also one of the new techniques that have been introduced in 5G systems to address mobility

problems. This technique enables the user to hold two connections with two serving base stations at the same time. For example, the user can hold a connection to one macro base station and another connection to a Pico or Femtocell, simultaneously [83]. The connections are performed over two separate signals, then the data streams are aggregated. Therefore, this technique can be defined as a technology that can combine two different technologies (i.e., 4G and 5G) to serve one user at the same time. This will significantly contribute in providing very high data rates to users by allowing them to use two different bands over two different technologies. Thus, the total user data rate is the aggregated data rate of the 4G speed and the 5G speed. A more stable connection is provided since the control data will be managed by macro base stations. The concept of dual connectivity is similar to the concept of Carrier Aggregation (CA) in LTE-A Release 10 to Release 13. In CA, the user can have multiple connections over different Component Carriers (CCs). One CC is always defined as a Primary Component Carrier (PCC), while the rest are defined as Secondary Component Carriers (SCCs). All control data, including the handover decision, are carried over the PCC only, while the SCCs are used to only carry the data stream. Dual connectivity has a similar concept; one radio link system can be used to carry control signals and also data stream, while the second radio link can be employed to only offer more data stream. This DC solution is a good solution for enhancing user speed during mobility as well as reducing mobility issues that result due to the implementation of mm-waves. However, the mobility issue will not be completely solved. Let us assume that the connection can be maintained with the macro base station, and frequent handover can occur over cells that use mm-waves. Thus, user mobility will continue when the user moves between cells. The optimal solution can be performed only by implementing smart handover techniques that can efficiently address the issue.

Although several handover self-optimization models for HPO [84-97], LBO, handover decision algorithms, and Dual Connectivity were introduced to address mobility problems [41-43, 46-49, 72, 78], there are no models or algorithms that exist which can optimally solve all mobility issues in future heterogeneous and homogeneous networks. Moreover, not all practical proposed models and algorithms have been investigated in 5G and 6G networks. Therefore, there is no guarantee on whether they can work efficiently in future heterogeneous networks or not. Most of them were designed and validated in previous networks, 4G, 3G, and 2G networks that use bands below 5GHz, while 5G and 6G networks will implement mm-wave bands. Consequently, innovating, designing, and developing advanced, efficient, and smart handover self-optimization models and handover decision algorithms for future heterogeneous networks are highly required.

V. CONCLUSION

In future mobile cellular systems, there will be several significant issues related to mobility management. This is mainly due to the implementation of mm-wave bands since they provide very small coverage. Mobility issues will further increase due to the ultra-dense deployment, massive growth of mobile connections, and the emergence of various mobile networks such as IoT, M2M, D2D, V2X, etc. Collectively, these will lead to a huge increase in the handover rate where several critical issues will occur such as the rise in handover failure probability, ping pong effect, and radio link failure during users' mobility. These will increase the interruption time, throughput degradation, and cell edge spectral efficiency. Although there are several solutions that have been proposed for addressing mobility problems, no optimal solution exists which can fully solve the issues in 5G and 6G networks. Thus, researchers and developers must address these technical issues and fully tackle the mobility challenges.

APPENDIX

ACKNOWLEDGMENT

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